The Development of an integrated monitoring and filtration system for performance assurance of hydraulic mould oscillation systems used in continuous casting machines at flat steel plants

Taher Salah El-Din, Karim El-Gewily, and Mohamed El-Shafie

EZDK-EZZ-Dekhila Steel Company/Utilities, Repair and Construction division, Central Repair Department, Alexandria-Matrouh highway – Dekhila – Alexandria, Egypt
E-Mail: melshafie@EZZSteel.com.eg

Abstract

In flat steel industry, a hydraulic mould oscillator (HMO) sophisticated mechanism is frequently used to provide oscillatory motion to the steel casting mould. The HMO system is highly sensitive to oil contamination, accordingly for the sustainability of operation, oil contamination level must be monitored and controlled to ensure that it meets system requirements. While continuous oil filtration had been practiced in EZDK Co. factory in past years, now a novel approach is being adopted that incorporates online monitoring of oil contamination level and its control via an external filtration unit. This approach lowers filtration unit electric power consumption and increases its service life-time.

Keywords: HMO, mould, oil cleanliness, oil filtration unit, servo, cylinder
Target audience: Mobile Hydraulics, metallurgical industries.

1 Introduction

In flat steel industry, a sophisticated hydraulic mould oscillator (HMO) mechanism is frequently used to provide an oscillatory motion to the steel casting mould (3) via two hydraulic servo cylinders (1) and (2) , as shown in Figure 1 /1/. The two electro-hydraulic servo cylinders (1) and (2) are driven by two hydraulic servo valves, one valve for each cylinder. The performance of the HMO system can be influenced by many parameters including oil contamination level of cylinders and valves.

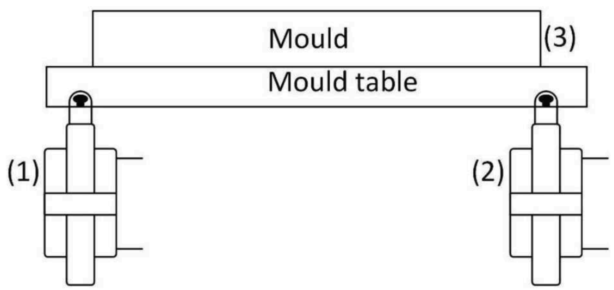

Figure 1: Hydraulic mould oscillator mechanism.

Thus oil contamination level has to be continuously monitored and controlled via a proper oil filtration unit /2/. Formerly continuous filtration was adopted in EZDK Co. factory, however in recent years with the significantly increasing costs of electric energy supply for domestic and industrial facilitates, it became necessary to seek a new approach. Accordingly a modern integrated solution has been introduced to maintain the required oil cleanliness level for the HMO system and decrease the running hours of the filtration unit, to lower its depreciation rate and increase service life time. The system consists of an on-line particle counter with electronic interface signal, an intermediate control system and a mobile oil filtration unit. The on-line particle counter sensor is connected in parallel with the pump delivery line that supplies oil to the servo valves, as shown in Figure 2. It samples and analyzes the delivery flow contamination and if the recorded contamination exceeds the permissible levels stated in the ISO 4406 standards, it automatically triggers a signal to the intermediate control circuit that starts the filtration unit till the triggering signal from the online particle counter is disabled. Figure 3 and Figure 4 show the layout of the system and the automatic control block diagram respectively.

Figure 2:On-line continuous monitoring sensor connected to the pump delivery line.

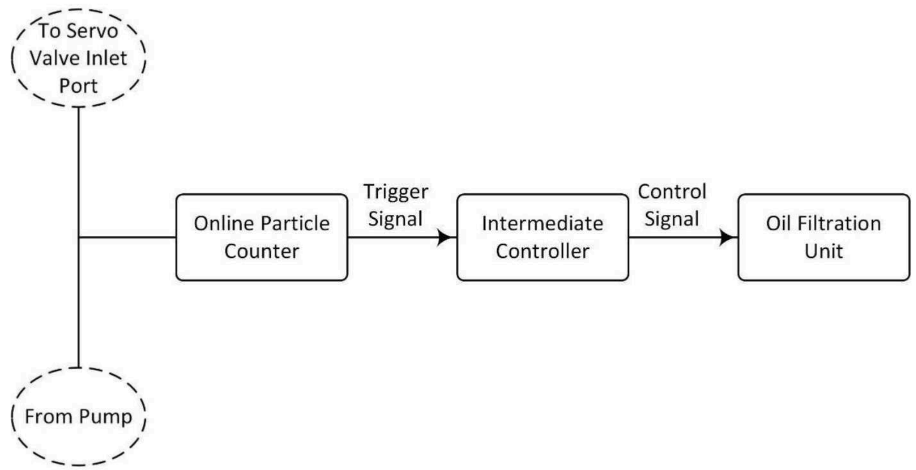

Figure 3: Layout of the system.

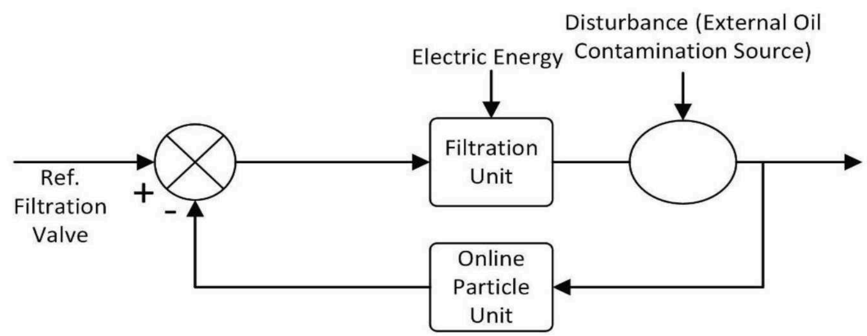

Figure 4: Block diagram of the monitoring and filtration system.

2 SYSTEM DESCRIPTION

2.1 The hydraulic circuit diagram of the HMO system

Figure 5 shows part of the hydraulic circuit diagram of the HMO system, which has an oil tank of capacity 3 m^3. Hydraulic power supply is provided via three axial piston pumps, each of geometric volume 125 cm^3 /rev., running at 1450 rpm, as well as one circulating screw pump of geometric volume = 132 cm^3 /rev, running at 1500 rpm for filtration and cooling purposes.

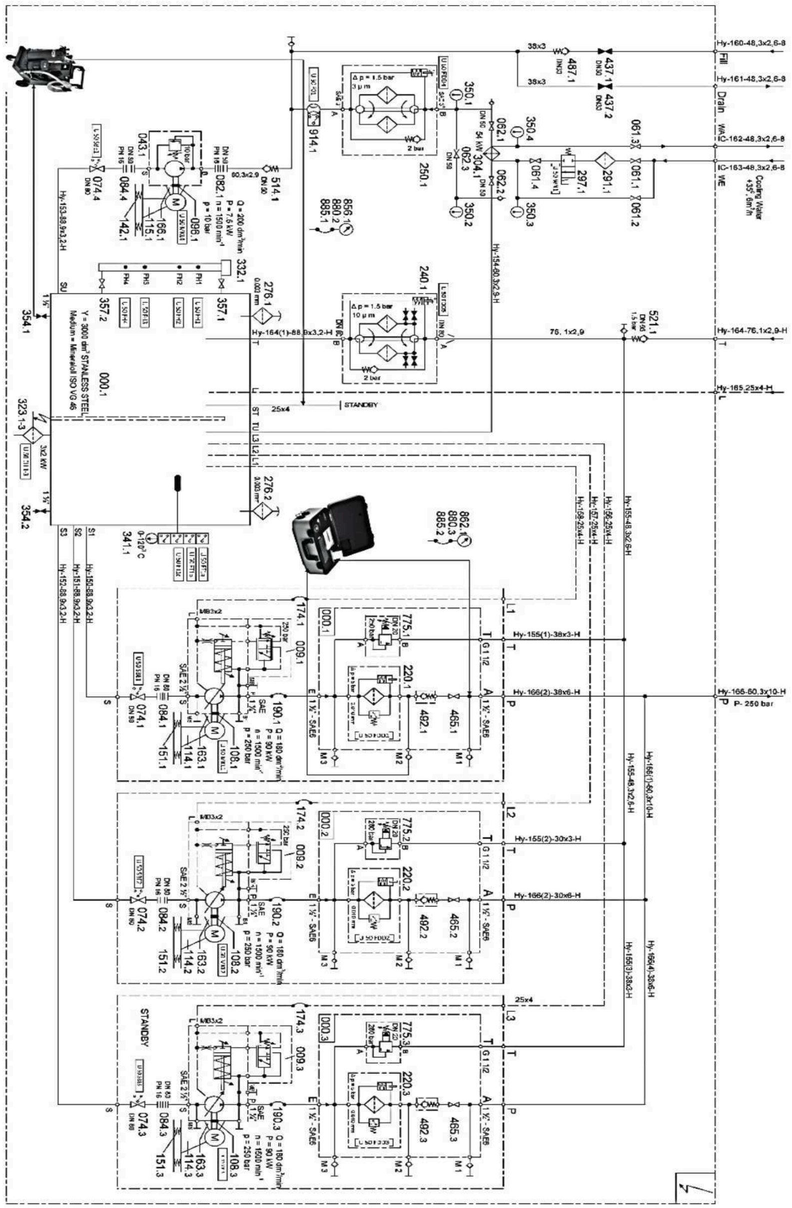

Figure 5: hydraulic circuit diagram of the HMO hydraulic system.

The pumps delivery line is equipped with one accumulator of 32 liter volume, and two manifold blocks mounted on the two servo cylinders that oscillate the mould mechanism, as shown in Figure 6. Each servo cylinder is driven separately via a hydraulic 3-stage servo valve.

The maximum pressure of the main hydraulic system is limited via the relief valve (No.775) to a pressure of 31.5 MPa. A high pressure filter (No.220) of filtrations 10 µm, filters the oil supplied by the pump. The pump delivery line includes a check valve (No.492), a shut off valve (No.465), an unloading valve (No.531) beside the accumulator (No.366).

The main filtration system of the HMO hydraulic system is composed of the twin inline filter unit for the main circulation system (No.250), pressure line filter (No.220) directly mounted at each pump delivery line, and the return line twin filter unit (No.240), in addition to a 3 µm fine filter allocated before servo valves (4) and (5).

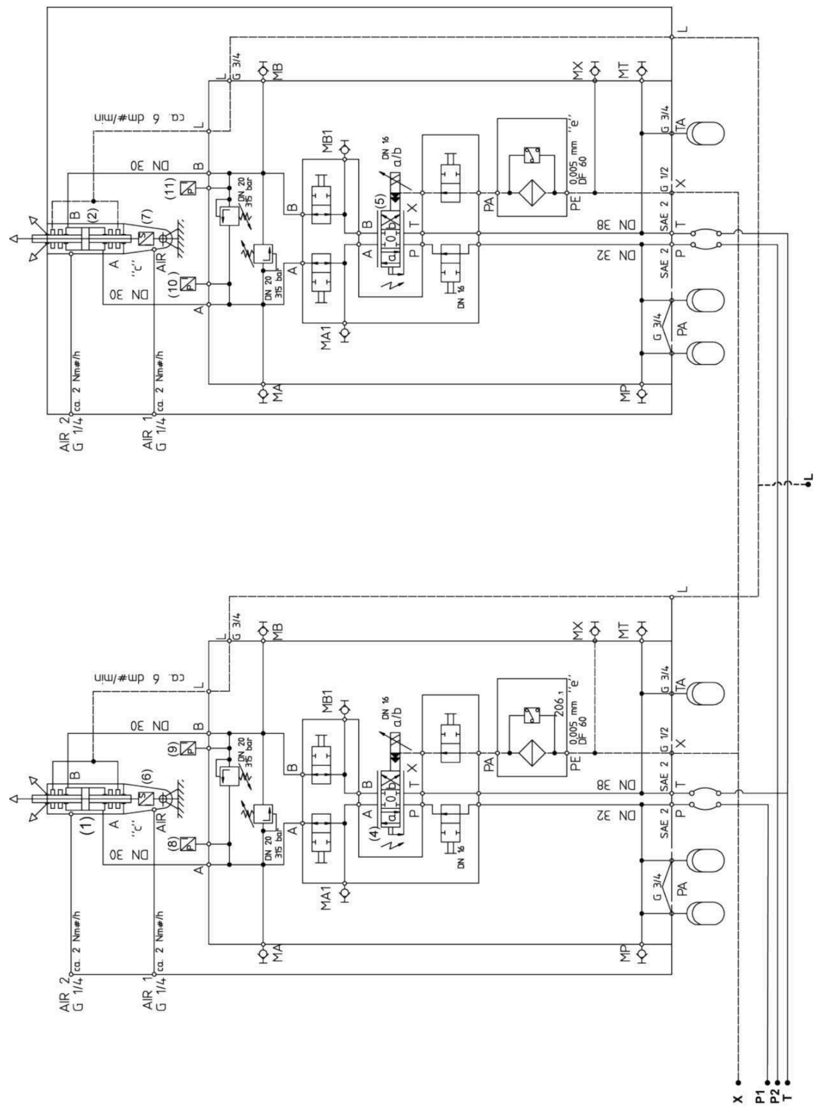

Figure 6: HMO mechanism.

In order to maintain HMO hydraulic system cleanliness below the critical value of permissible degree of contamination of pressure fluid which is 18/16/13 contamination class according to ISO 4406 /3/, an external filtration unit of type OFU10 was connected for years to the hydraulic tank and was run on a continuous basis for several weeks. An oil sample was taken every 4 weeks and tested to indicate the oil cleanliness level, and accordingly a decision was made to either keep the external filtration unit working or to disconnect it. Naturally this approach results in excessive power loss and rapid depreciation of the filtration unit. The continuous operation of the external filtration unit was found to consume about 2160kWhr per month.

2.2 Contamination sources in HMO

Contamination sources found in the HMO system are classified as external and internal sources of contamination. External sources of contamination come from exchanged parts such as hoses and valves as a result of routine maintenance activities .After parts exchange some dust and fibres enter in the system, while internal sources of oil contamination result of component wear during the normal operation of moving components such as axial piston pumps and servo cylinders.
Main wear metal elements found in this system are copper, chromium, iron and silicon, with an average concentration of 35, 24, 29 and 22 ppm respectively.

2.3 On-line particle counter type HIAC [PM4000]

This device is designed to measure and quantify the number of solid contaminants in hydraulic oils. The HIAC -PM4000 is a laboratory accurate instrument suitable for "on-site'' applications utilizing mineral oil as the operating fluid in the HMO /4/. The operation principle is based on light extinction, whereby a laser light beam passes through the fluid and hits on photodiodes. When a particle cut the beam it reduces the amount of light received by the diode, and from this change in the amount of received light, the size of the particle can be detected. Figure 7 shows the particle counter unit.
The particle counter has an alarm limit setting according to ISO codes for each particle size, and the alarm LED is activated (flickers) when this limit is exceeded.

Figure 7: HIAC on-line particle counter type PM4000

2.4 Mobile filtration unit type HYDAC [OFU10]

The mobile filtration unit shown in figure 8 is used as an external filtration unit. It has a constant displacement pump of a flow rate of 100 l/ min that runs at a speed of 1500 rpm. It can filter all the oil in the HMO oil tank, of volume 3 m^3 that contains about 2000 lit of oil, in about 20 minutes for one filtration cycle. The filteration pump delivers the oil consequently to a 5 µm filter as shown in figure 9 , before returning to the HMO tank /5/.

Figure 8: Hydac mobile filtration unit.

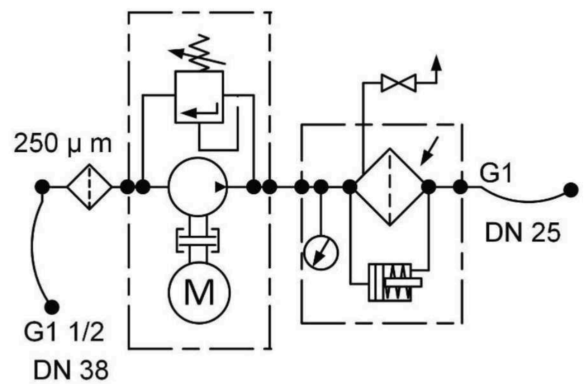

Figure 9: Hydac Mobile Filtration Circuit.

2.5 The Concept of the Detection/ Trigger System

The detection/ trigger system depends on the results recorded by the HIAC-PM4000 online particle counter, which flickers the alarm LED when the contamination level exceeds the ISO coded programmed limits. At the start of HIAC PM4000 the alarm LED flickers 4 times as an indication of system start up. To employ the alarm for contamination detection, a controller with dedicated logic must be interfaced with the particle counter. The detection is done by connecting the pins of the alarm LED from the particle counter to an ARDUINO UNO controller board and then the number of pulses(flickers) received from the LED pins are recorded. If the number of pulses exceeds 4 which is the start-up normal check up number, the controller will give a trigger signal to external relay to activate the filtration unit for a period of 20 minutes and then a reset signal is sent by the controller to stop the filtration unit and reset the particle counter alarm.

2.6 Control System

The control system is based on ARDUINO UNO controller board, set of relays, and a 3-phase contactor for powering the filtration unit as shown in Figure 9.

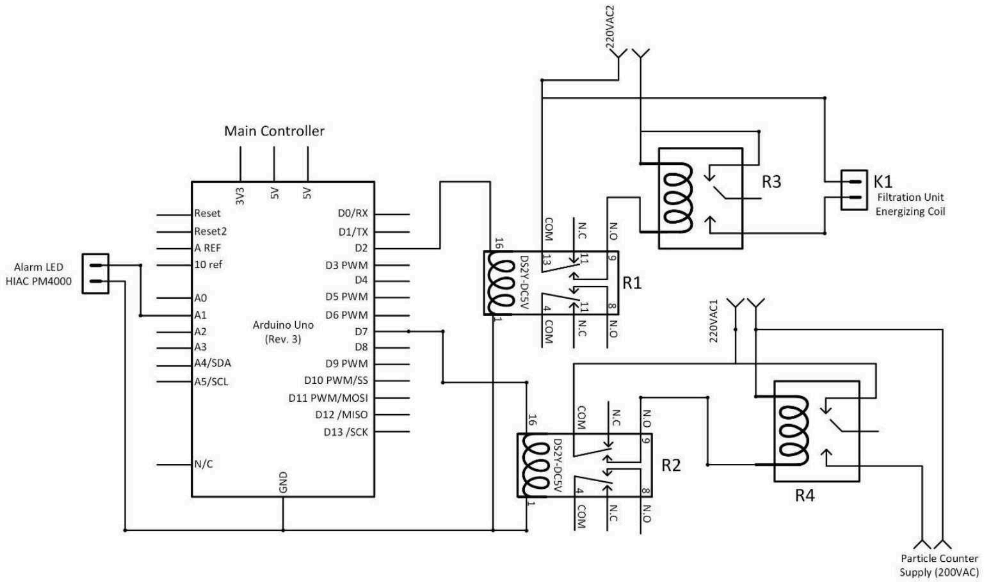

Figure 9: Schematic of control system.

3 Experimental work and results

The concept of contamination detection/ trigger of filtration unit depends on the number of flickers received from the particle counter alarm LED. The alarm in the particle counter device has been set to respond to the contamination level per millilitre for particles with a size larger than 4 µm, with target 18/16/13contamination class according to ISO 4406-1999. The alarm setting is shown in Figure 10. The controller is designed to wait for 15 incoming pulses “1”after the 4 pulses resulting at the start of work. After these 15 pulses have been counted “2”, a trigger signal “3” is initiated to start the filtration unit as shown in Figure 11.The filtration unit would run for 20 minutes after receiving the starting signal from the controller then, it will be shut down due to triggering signal being reset by the controller as shown in Figure 12.

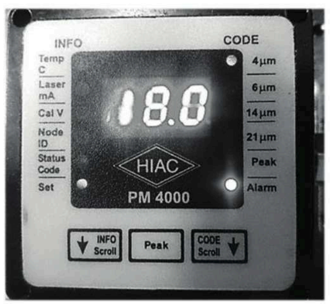

Figure 10: Alarm setting for 4µm particles with target ISO code 18/16/13 according to ISO 4406.

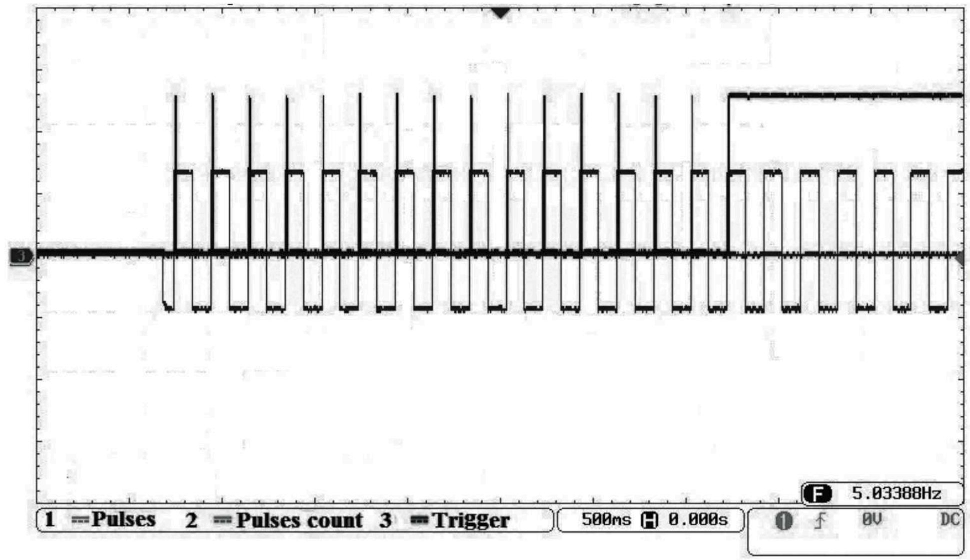

Figure 11: Trigger signal “3” goes up after set of pulses.

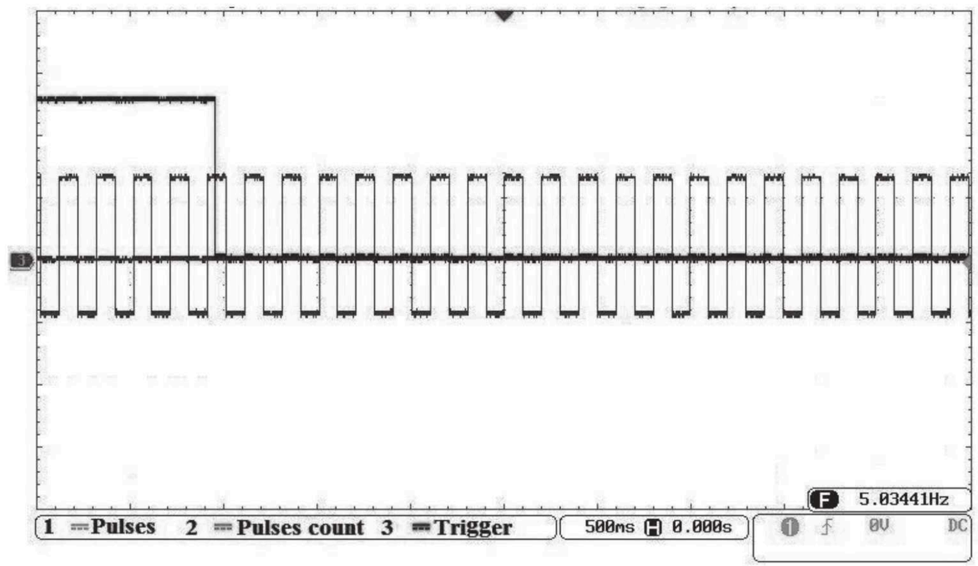

Figure 12: Trigger signal goes down after a period of time.

4 Summary and Conclusion

In any running hydraulic system, there are several sources of oil contamination. The usage of an on-line particle counter can be more effective compared with off-line monitoring, maintenance procedures based on periodical physical sampling and analysis either in an onsite or off-site laboratory. Equipped laboratories can run complete diagnostic checks on the lubricant, but in some cases it can take up to several days or even weeks to obtain the oil analysis results. In the meantime, an unreliable system component may by then have completely failed, resulting in productivity downtime and major repair expenses. On the other hand, the continuous operation of the filtration system consumes power (when the contamination is eliminated), moreover this will decrease the life expectancy of the filtration unit. A control system is implemented to achieve filtration unit operation based the on-line particle counter when the contamination level reaches the set limit value, this allows good utilization for the filtration unit, saving power consumption by approximately 96 % and monthly reduction of the unit service hours by 680 hours.

Tests have been carried out on the HMO hydraulic system and results have confirmed the high reliability of the filtration/on-line monitoring device.

With such a system, considerable positive development on operation and maintenance costs of hydraulic servo systems can be realized.

5 Acknowledgements

The authors wish to expresses their sincere gratitude to EZDK Co. management for their support that enabled the implementation of this project. Thanks are also due to Professor Saad Kasem for his keen review of the present paper.

References

/1/ SMS DEMAG GmbH. 2002. Hydraulic mould oscillation functional description.

/2/ Salah El-din, T. 2010. Enhancement of Performance of an Electrohydraulic Servo System for Mould Oscillation Control in Continues Casting Machines. Ph.D. thesis, Faculty of Engineering, Cairo University, Egypt.

/3/ Bosch Rexroth,datasheetRE29595/10.02, Servo valve, 4-way version - Type 4WSE3EE.

/4/ HIAC,6 December 2007 - Edition 5,particle Counter PM4000, operator manual, RPS.

/5/ Hydac, OFU10, datasheet EN7936-4-09-17, filter pump transfer unit.